06EC756 - IMAGE PROCESSING

A picture is worth a thousand words

SIDDIQ IQBAL,
Dept Of TCE,
BMSIT

IMAGE PROCESSING

Subject Code : **06EC756** IA Marks : 25

No. of Lecture Hrs/ Week : 04 Exam Hrs : 03

Total no. of Lecture Hrs. : 52 Exam Marks : 100

PART - A

UNIT – 1 **6 Hours**

DIGITAL IMAGE FUNDAMENTALS: What is Digital Image Processing. Fundamental Steps in Digital Image Processing, Components of an Image processing system, elements of Visual Perception.

UNIT – 2 **6 Hours**

IMAGE SENSING AND ACQUISITION: Image Sampling and Quantization, Some Basic Relationships between Pixels, Linear and Nonlinear Operations.

UNIT – 3 **6 Hours**

IMAGE TRANSFORMS: Two-dimensional orthogonal & unitary transforms, properties of unitary transform, two dimensional discrete Fourier transform.

UNIT – 4 **6 Hours**

Discrete cosine transform, sine transform, Hadamard transform, Haar transform, Slant transform, KL transform.

PART - B

UNIT – 5 **6 Hours**

IMAGE ENHANCEMENT: Image Enhancement in Spatial domain, Some Basic Gray Level Transformations, Histogram Processing, Enhancement Using Arithmetic/Logic Operations.

UNIT – 6 **6 Hours**

Basics of Spatial Filtering Image enhancement in the Frequency Domain filters, Smoothing Frequency Domain filters, Sharpening Frequency Domain filters, homomorphic filtering.

UNIT – 7 **10 Hours**

Model of image degradation/restoration process, noise models, Restoration in the Presence of Noise, Only-Spatial Filtering Periodic Noise Reduction by Frequency Domain Filtering, Linear Position-Invariant Degradations, inverse filtering, minimum mean square error (Weiner) Filtering.

UNIT – 8 **6 Hours**

COLOR FUNDAMENTALS: Color Models, Pseudo color Image Processing., processing basics of full color image processing.

TEXT BOOK:

- **Digital Image processing**– Rafael C. Gonzalez and Richard E. Woods, Pearson Education, 2001, 2nd edition.

REFERENCE BOOKS:

1. **Fundamentals of Digital Image Processing**– Anil K. Jain, Pearson Edun, 2001.
2. **Digital Image Processing and Analysis** – B. Chanda and D. Dutta Majumdar, PHI, 2003.

Unit1 : Contents

- Introduction: What is Digital Image Processing ?
- Fundamental steps in Digital Image Processing
- Components of an Image processing system
- Elements of Visual Perception

INTRODUCTION

- **Image:** a 2D function *f(x,y), where x & y are* spatial coordinates & the amplitude *f at any pair of coordinates (x,y) is called the intensity or gray level*
  - When *x, y, & f are discrete quantities the image is* ***digital***
  - Gray-level image will be represented by a matrix with 8-bit integer values, in the range [0=black, 255=white]

- Digital Image **Processing-** concerns the transformation of an image to a digital format & its processing by a computer or by dedicated H/W - both I/P & O/P are digital images
- Digital Image **Analysis-** concerns the description & recognition of the image contents - I/P is a digital image, the O/P is a symbolic description
- **Computer Vision**- uses digital electronics to emulate human vision, including learning, making inferences, & taking actions

Several fields deal with images

Input/Output	Image	Description
Image	Image Processing	Computer Vision
Description	Computer Graphics	AI

2 Principal application areas

1. Improvement of pictorial information for human interpretation
2. Processing of image data for storage, transmission, & representation for autonomous machine perception

- Eg: Categorize by image sources
  - Radiation from the Electromagnetic spectrum
  - Acoustic
  - Ultrasonic
  - Electronic (in the form of electron beams used in electron microscopy)
  - Computer (synthetic images used for modeling & visualization)

3 types of computerized processes

1. **Low**-level : I/Ps & O/Ps are images
   - Primitive operations such as image preprocessing to reduce noise, contrast enhancement & image sharpening

2. **Mid**-level : I/Ps may be images, O/Ps are attributes extracted from those images
   - Segmentation
   - Description of objects
   - Classification of individual objects

3. **High**-level :
   - Image analysis

FUNDAMENTAL STEPS IN DIGITAL IMAGE PROCESSING

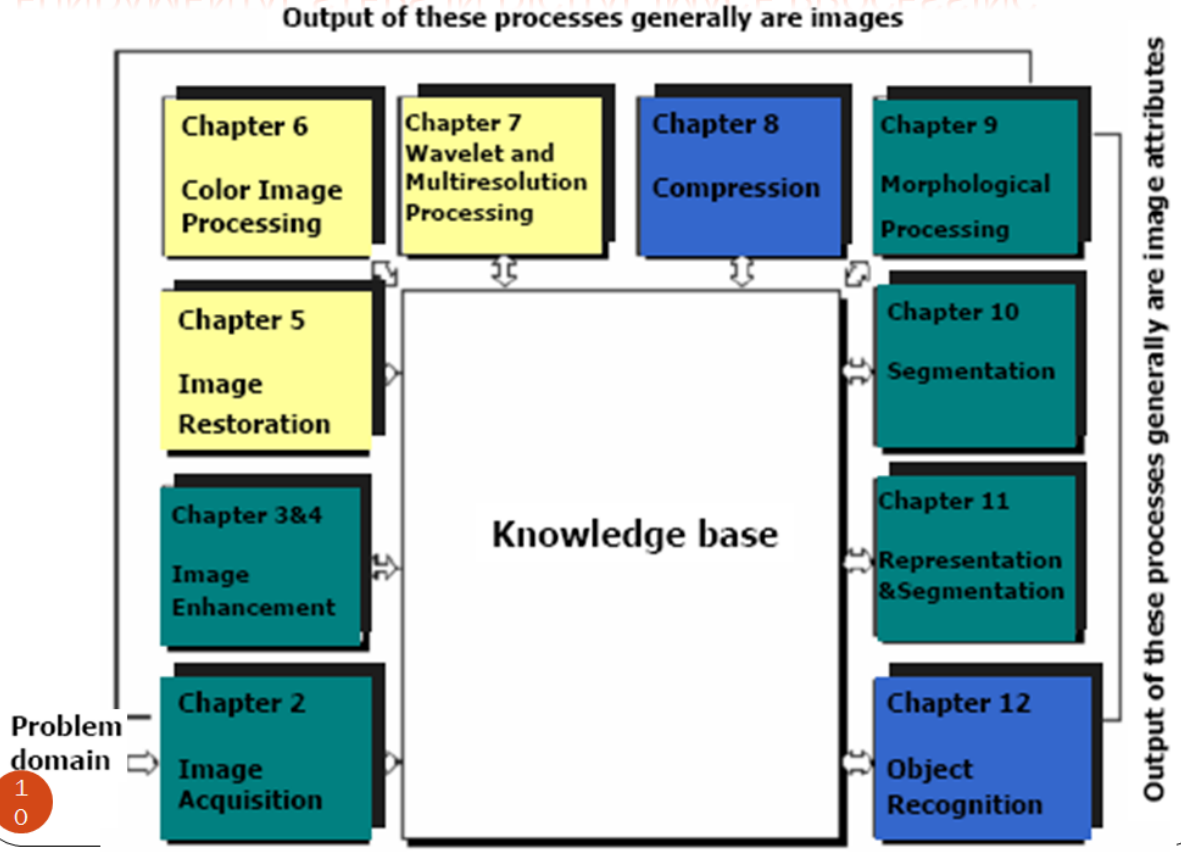


Image Acquisition:

- An image is captured by a sensor (such as a monochrome or color TV camera) & digitized
- If the O/P of the camera or sensor is not already in digital form, an ADC converter digitizes it

IMAGE ENHANCEMENT:

- To bring out detail that is obscured, or simply to highlight certain features of interest in an image

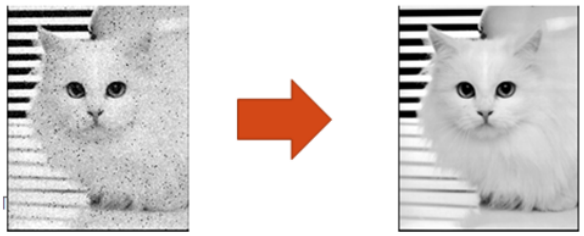


Image Restoration

- Improving the appearance of an image
- Tend to be based on mathematical or probabilistic models of image degradation

COLOR IMAGE PROCESSING

- Gaining in importance because of the significant increase in the use of digital images over the Internet

Wavelets

- Foundation for representing images in various degrees of resolution
- Used in image data compression & pyramidal representation (images are subdivided successively into smaller Regions)

COMPRESSION:

- Reducing the storage space required to save an image or the BW required to transmit it
- Ex. JPEG (Joint Photographic Experts Group) image compression standard

Morphological processing

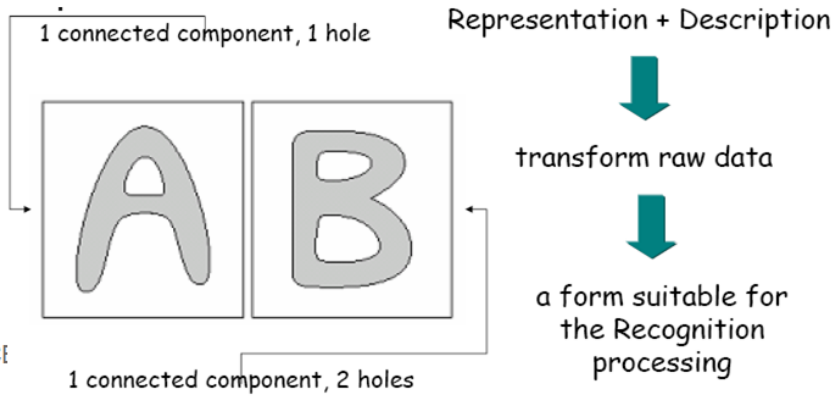
- Deals with Tools for extracting image components that are useful in the representation & description of shape

SEGMENTATION

- **Partitions** an image into its constituent parts or objects
  - It is one of the most difficult tasks in DIP
  - A rugged segmentation procedure brings the process a long way toward successful solution of imaging problems that require objects to be identified individually
  - O/P of the segmentation stage is raw pixel data, constituting either the boundary of a region or all the points in the region itself

Representation & Description

- Representation → make a decision whether the data should be represented as a boundary or as a complete region
  1. Boundary representation → focus on external shape characteristics, such as corners & inflections
  2. Region representation → focus on internal properties, such as texture or skeleton shape
- Description(feature selection), deals with extracting attributes



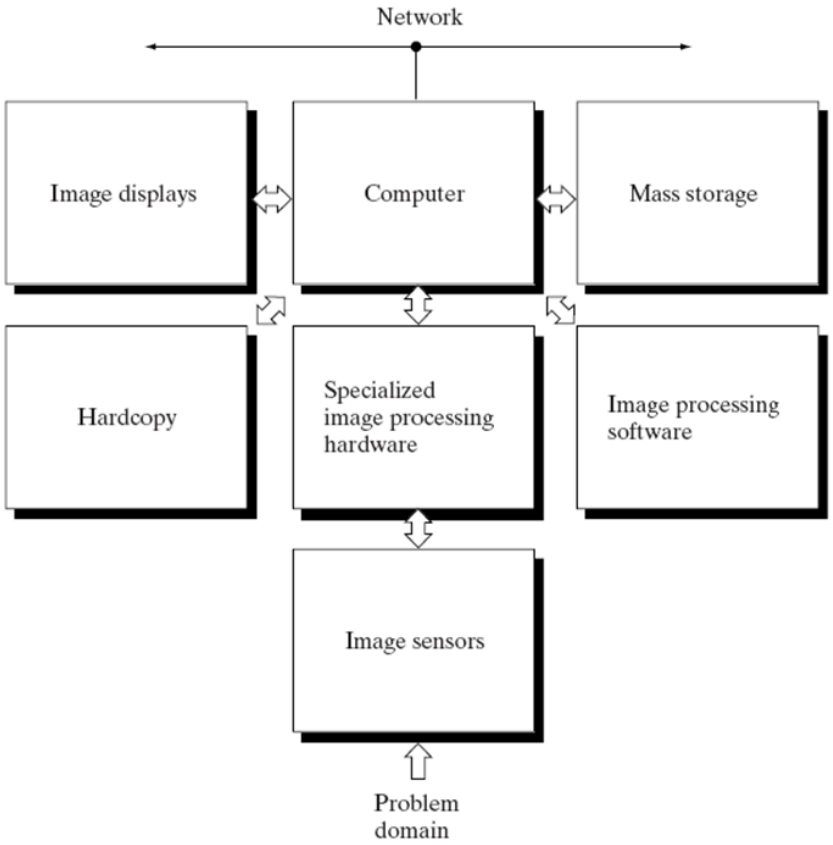
Recognition & Interpretation

- Recognition → the process that assigns a label to an object based on the information provided by its descriptors
- Interpretation → assigning meaning to an ensemble of recognized objects

KNOWLEDGE BASE:

- A problem domain detailing regions of an image where the information of interest is known to be located
- Help to limit the search

COMPONENTS OF A GENERAL-PURPOSE IMAGE PROCESSING SYSTEM :



- ***Image acquisition:*** This is carried out by sensors. Sensing involves 2 elements, namely
  - **Physical device** that is sensitive to the energy radiated by the object we wish to image &
  - **Digitizer** that converts the o/p of the physical sensing device into digital form
- ***Specialized image processing hardware*** consists of a digitizer & an ALU used for performing arithmetic or logical operations on the image
- ***Computer*** is used for performing off line image processing tasks. Computer can range from a general PC to a super computer
- ***Software*** for image processing consists of specialized modules that perform specific tasks on the image

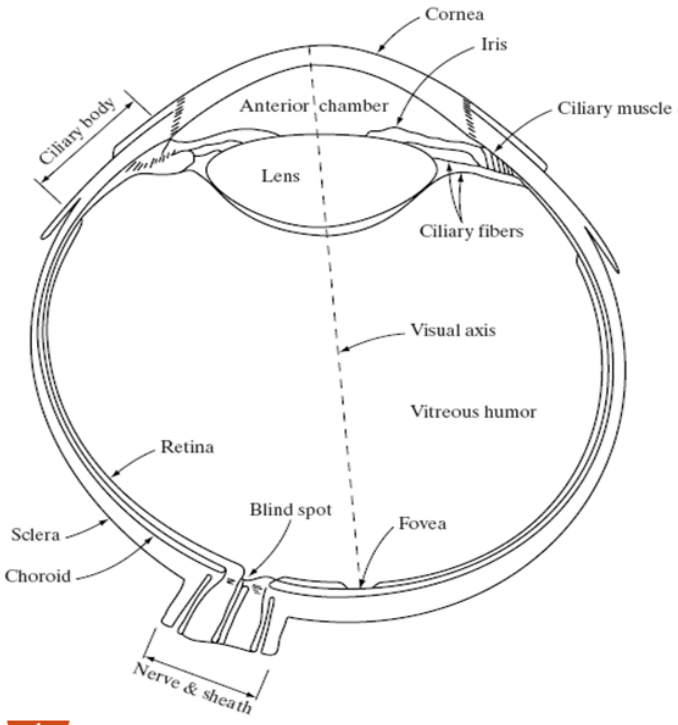
- **Mass Storage** is essential in image processing applications. 3 categories of digital storage required:
  1. **Short Term Storage:** required during **processing**. **Frame Buffers** that can store 1 or 2 images at a time & allows image zooming, scrolling & panning are used for short term storage
  2. **On Line Storage:** for **fast recall**. Magnetic disks or optical media storage is used for online storage
  3. **Archival Storage:** for **infrequent** access. Magnetic tapes & optical disks are used for archival storage

- **Image Displays** consists of **monitors**, they are driven by o/ps of image & graphic display cards
- **Hardcopy** devices for recording images include laser printers, film cameras, heat sensitive devices, inkjet units and digital units such as optical & CDROM disks
- **Networking** is vital function, because it is necessary to transmit images. During transmission BW is the key factor to be considered

HUMAN & COMPUTER VISION

- We can't think of image processing without considering the human vision system
- We observe & evaluate the images that we process with our visual system
- Without taking this elementary fact into consideration, we may be much misled in the interpretation of images

Structure of the Human Eye



- Shape is nearly a sphere
- Average diameter = 20 mm
- 3 membranes:
  1. Cornea & Sclera – outer cover
  2. Choroid
  3. Retina -enclose the eye

Contd..

- **Cornea** : tough, transparent tissue, covers the anterior surface of the eye
- **Sclera :** Opaque membrane, encloses the remainder of the optic globe
- **Choroid :**
  - Lies below the sclera, contains n/w of blood vessels that serve as the major source of nutrition to the eye
  - Choroid coat is heavily pigmented & hence helps to reduce the amount of extraneous light entering the eye & the backscatter within the optical globe.

Contd... Lens & Retina

Lens:

- Infrared & ultraviolet light are absorbed appreciably by proteins within the lens structure &, in excessive amounts, can cause damage to the eye

Retina:

- Innermost membrane of the eye which lines inside of the wall's entire posterior portion. When the eye is properly focused, light from an object outside the eye is imaged on the retina

Receptors

- Pattern vision is afforded by the distribution of discrete light receptors over the surface of the retina

- Receptors are divided into 2 classes:
  1. Cones
  2. Rods

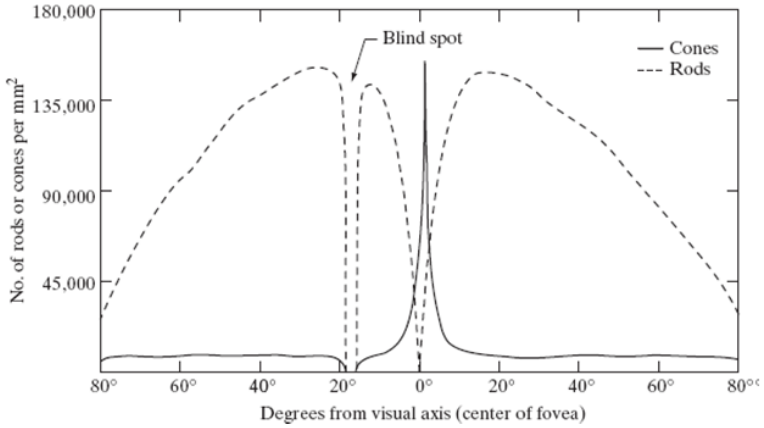
Cones

- 6-7 million, located primarily in the central portion of the retina (the fovea, muscles controlling the eye rotate the eyeball until the image falls on the fovea)
- Highly sensitive to color
- **Each is connected to its own nerve end** thus human can resolve fine details
- Cone vision is called **photopic** or **bright**-light vision

Rods

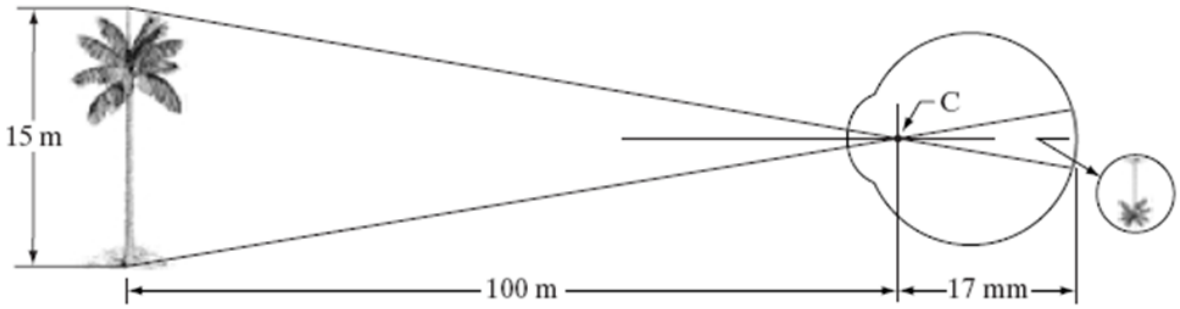
- 75-150 million, distributed over the retina surface
- **Several rods are connected to a single nerve** end reduce the amount of detail discernible
- Serve to give a general, overall picture of the field of view
- Sensitive to low levels of illumination
- Rod vision is called **scotopic** or **dim**-light vision

Cross section of the right eye



- Blind spot → the absence of receptors area
- Receptor density is measured in degrees from the fovea
- Cones are most dense in the center of the retina (in the area of the fovea)
- Rods increase in density from the center out to approx. 20° off axis & then decrease in density out to the extreme periphery of the retina

Image Formation in the Eye

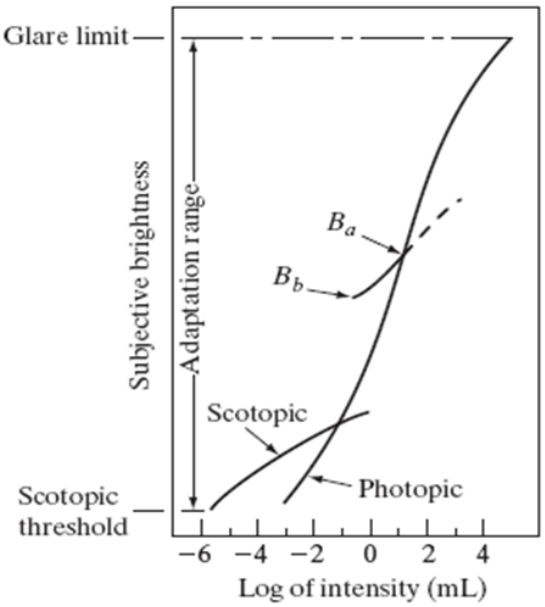


- Principal difference b/w the **lens of the eye** & an ordinary optical lens is that the former is **flexible**
- Radius of curvature → the anterior surface > its posterior surface
- Shape → is controlled by tension in the fibers of the ciliary body
- Focus
  - On **distant** objects, the controlling muscles cause the lens to be relatively **flattened**
  - these muscles allow the lens to become **thicker** in order to focus on objects **near** the eye

- When the eye focuses on an object **farther** away than about 3m, the lens exhibits its **lowest** refractive power
- When the eye focuses on a **nearby** object, the lens is most **strongly** refractive
- This information makes it easy to calculate the size of the retinal image of any object
- 15/100=h/17 or h=2.55 mm

Brightness adaptation & discrimination

- The eye can adapt to an enormous range (in the order of 10^10) of light intensity, from **scotopic threshold to** the glare limit
- Subjective brightness (i.e. perceived intensity) is a log function of the light intensity incident on the eye
- In **photopic vision alone, the** range is about 10^6



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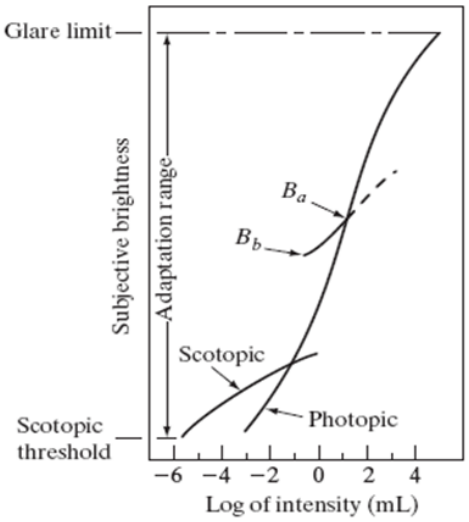
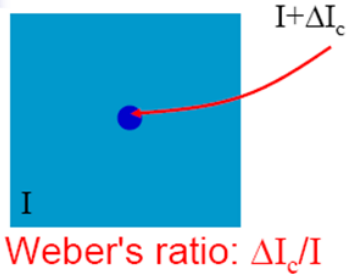
- **Brightness adaptation :** Visual system cannot operate over such a huge range simultaneously; instead, it changes its overall sensitivity
- E.g.: if the eye is adapted to brightness level B_a, the short intersecting curve represents the range of subjective brightness perceived by the eye. The range is rather restricted, i.e. below level B_b all stimuli are perceived as black
- The upper part of the curve (dashed) is not restricted, but when extended too far it looses its meaning as it raises the adaptation level higher than B_a



Weber ratio: Contrast sensitivity

Experiment for Brightness discrimination

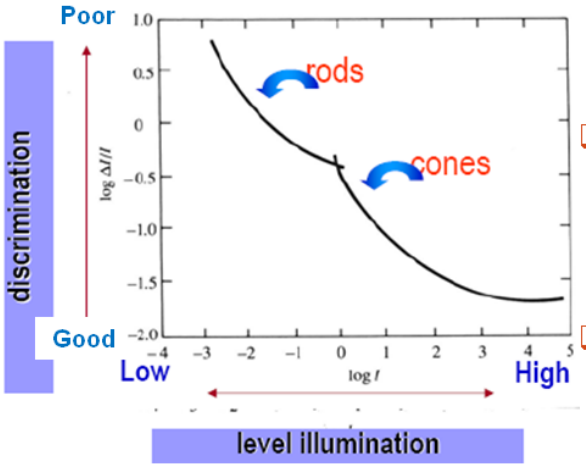


Weber's ratio: $\Delta I_c/I$

- Ability of the eye to discriminate b/w changes in brightness at any specific adaptation level is of considerable interest
- Look at a flat, uniformly illuminated large area, e.g. a large opaque glass illuminated from behind by a light source with intensity I
- Add an increment of illumination ΔIc, in the form of a short duration flash as a circle in the middle. Vary ΔIc & observe the result. The results should move from "no perceivable change" to "perceived change". Fraction ΔIc/I for which ΔIc produces "just perceivable change" is called the **Weber ratio**

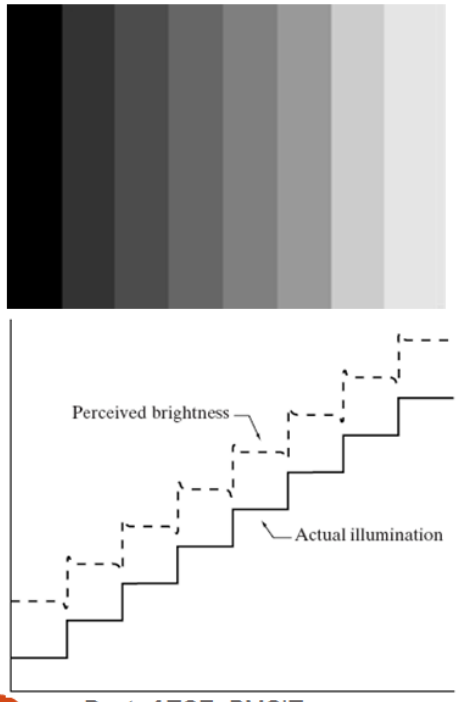
Good brightness discrimination → ΔIc/I is small
Bad brightness discrimination → ΔIc/I is large

Contd...



- Brightness discrimination is poor (the Weber ratio is large) at low levels of illumination & improves significantly (the ratio decreases) as background illumination increases
- It is difficult to distinguish the discrimination when it is bright area but easier when the discrimination is on a dark area
- 2 branches illustrate the fact that at low levels of illumination vision is carried out by the rods, whereas at high levels, cones are at work

Brightness VS Function of intensity

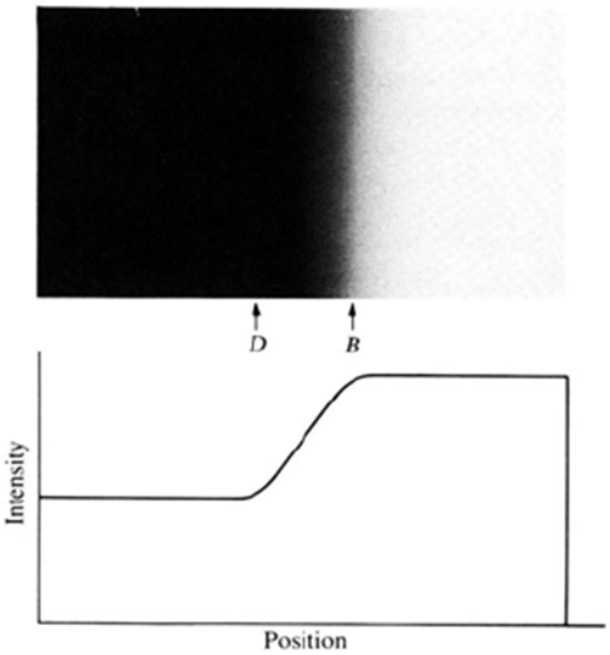


Mach band pattern

- Brightness is not a simple function of intensity
- Visual system tends to undershoot or overshoot around the boundary of regions of different intensities
- The intensity of the stripes is constant but we actually perceive a brightness pattern is strongly scalloped near the boundaries

Contd...

Is it the same level of darkness around area D & B ?



- Brightness pattern perceived is a darker stripe in region D & a brighter one in the region B whereas actually the region from D to B has the same intensity

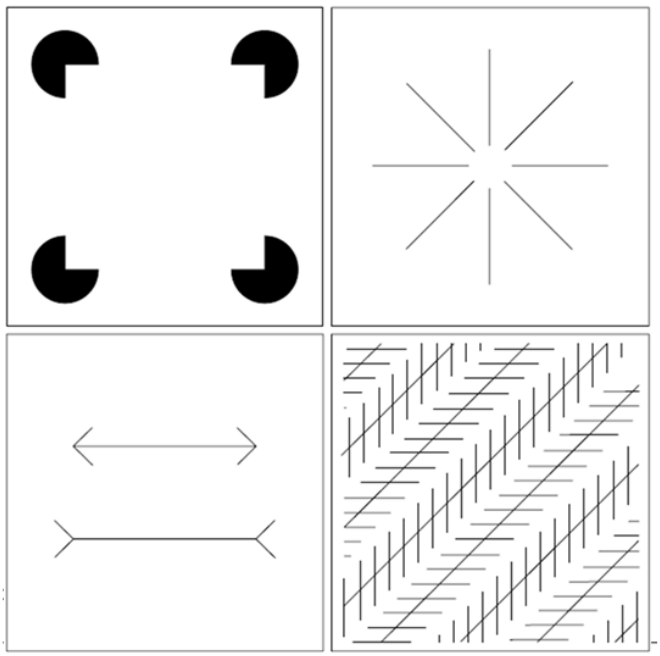
Simultaneous contrast

Which small square is the darkest one ?

- All the small squares have exactly the same intensity, but they appear to the eye progressively darker as the background becomes brighter

- Region's perceived brightness does not depend simply on its intensity

Human Perception Phenomena



OPTICAL ILLUSIONS